Modal Mapping in A Complex Shallow Water Environment

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LONG-TERM GOAL

The long-term goal of this research is to increase our understanding of shallow water acoustic propagation and its relationship to the three-dimensionally varying geoacoustic properties of the seabed.

OBJECTIVES

The scientific objectives of this research are: (1) to develop high-resolution methods for characterizing the spatial and temporal behavior of the normal mode field in shallow water; (2) to use this characterization as input data to inversion techniques for inferring the acoustic properties of the shallow water waveguide; and (3) to use this characterization to improve our ability to localize and track sources.

APPROACH

An experimental technique is being developed for mapping the wavenumber spectrum of the normal mode field as a function of position in a complex, shallow water waveguide environment whose acoustic properties vary in three spatial dimensions. By describing the spatially varying spectral content of the modal field, the method provides a direct measure of the propagation characteristics of the waveguide. The resulting model maps can also be used as input data to inverse techniques for obtaining the acoustic properties of the waveguide. The experimental configuration consists of a fixed source radiating one or more pure tones to a field of freely drifting buoys, each containing a hydrophone, GPS and acoustic navigation, and radio telemetry. In this context, two-dimensional modal maps in range *and* azimuth, as well as three-dimensional bottom inversion in range, depth, *and* azimuth, become achievable goals.

WORK COMPLETED

The Modal Mapping Experiment (MOMAX) was conducted aboard the R/V Endeavor during the period 21 March - 3 April 1997. A series of eight experiments was carried out in the East Coast STRATAFORM/SWARM area off the New Jersey coast in about 70 m of water. Three drifting buoys received signals at ranges of up to 10 km from sources deployed in one of two configurations: (1) an NRL J15-3 source suspended from the ship (drifting or underway) at a depth of 30 m and transmitting pure tones at 50, 75, 125, and 175 Hz; and (2) a Webb source moored 1 m above the bottom and radiating pure tones at 200 and 300 Hz. In both cases, the nominal source level was 170 dB re 1 μPa @ 1 m. In addition to the acoustic measurements, the following environmental data were recorded: (1) 3-6 kHz chirp sonar subbottom data along every buoy and source track; (2) numerous CTD casts

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throughout the region; and (3) Seamon temperature logger data at several depths on each drifter buoy and on the Webb source mooring.

RESULTS

This year our work focused on the reduction and preliminary analysis of the MOMAX data set. This effort concentrated on four primary areas: (1) The merging of the large volume of pressure field and navigation measurements as a function of time to obtain pressure field data vs. position. (2) The application of high-resolution spectral estimation techniques that enable the transformation of these data from the space domain to the wavenumber domain over short spatial apertures, thereby generating modal maps which show the spatial variability of the waveguide. (3) The initial development of a theory for explaining the remarkable stability and regularity of the measured signal phases, even though the magnitudes exhibit complex, multimodal interference patterns. (4) The demonstration, using the MOMAX GPS data, that the distance to drifting buoys several kilometers away from a moving ship can be determined to centimeter-level accuracy over a broad range of sea states.

In a related effort, we conducted extensive numerical simulations of a new bottom impedance measurement technique under development in our group and thereby demonstrated its great potential for solving the problem of measuring bottom loss at mid-to-high frequencies in shallow water. This technique has an advantage over other shallow water bottom characterization methods in that it does not require the identification of individual modes or ray paths.

IMPACT/APPLICATIONS

The experimental configuration consisting of a CW source and freely drifting buoys will provide a simple way to characterize a shallow water area and may be useful in survey operations. In addition, the planar, synthetic receiving array may offer an effective new technique for localizing and tracking CW sources in shallow water.

TRANSITIONS

The synthetic aperture technique and Hankel transform inversion methodology which underlies the modal mapping method has been implemented in the ACT II experiment, sponsored by DARPA and ONR. This approach has also been adopted by several research groups internationally.

RELATED PROJECTS

MOMAX was conducted in the same area off the New Jersey coast where the ONR-sponsored STRATAFORM and SWARM experiments were carried out. The extensive geophysical, seismic, acoustic, and oceanographic data obtained in the latter two experiments will be used to ground truth the MOMAX measurements.

In addition, a collaborative effort was initiated with Professor Joyce McLaughlin's group in the Mathematical Sciences Department at the Rensselaer Polytechnic Institute. We are working together to apply exact, analytic inverse techniques developed with partial ONR support by her group to the

problem of inverting for the geoacoustic properties of the seabed using our shallow water acoustic measurements as input data.

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